GEOLOGY

3

Yellowstone National Park's unique physical landscape has been and is being created by many geological forces. Here, some of the Earth's most active volcanic, hydrothermal (water + heat) and earthquake systems make this national park a priceless treasure. In fact, Yellowstone was established as the world's first national park primarily because of its extraordinary geysers, hot springs, mudpots and steam vents, and other unique geologic wonders such as the Grand Canyon of the Yellowstone River.

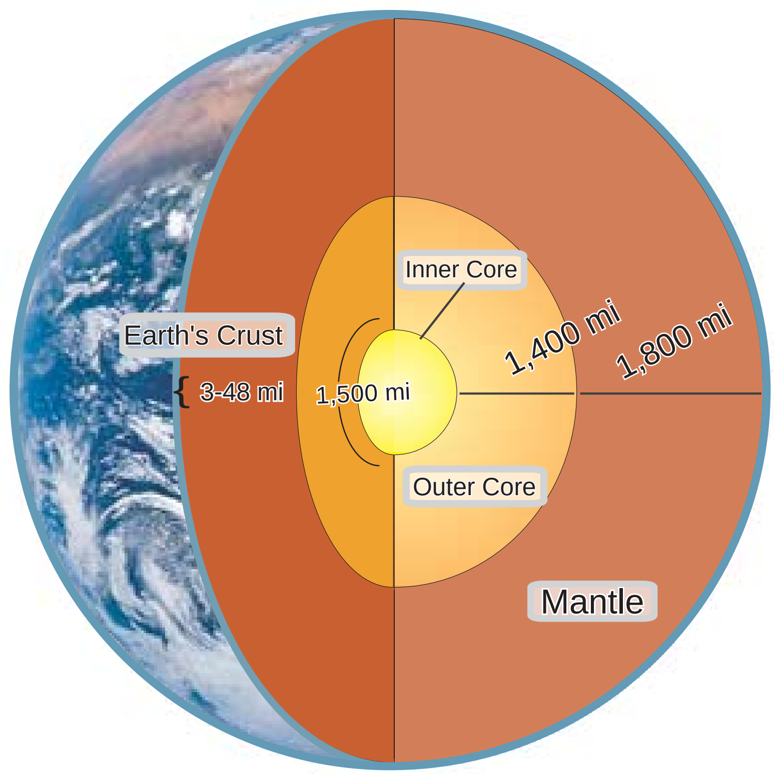
YELLOWSTONE'S GEOLOGIC SIGNIFICANCE

- One of the most geologically dynamic areas on Earth due to a rare continental hotspot that causes volcanic activity.
- One of the largest volcanic eruptions known to have occurred in the world, creating one of the largest known calderas.
- More than 10,000 hydrothermal features, including more than 300 geysers.
- The largest concentration of active geysers in the world—approximately half of the world's total.
- Most of the undisturbed geyser basins left in the world (Kamchatka Peninsula has the others; the rest have been modified or destroyed by human development).
- One of the few places in the world where active travertine terraces are found, at Mammoth Hot Springs.
- Site of many petrified trees resulting from repeated volcanic eruptions over the ages.

What Lies Beneath

Yellowstone's geologic story provides examples of how geologic processes work on a planetary scale. The foundation to understanding this story begins with the structure of the Earth and how this structure gives rise to forces that shape the planet's surface.

The Earth is frequently depicted as a ball with a central core surrounded by concentric layers that culminate in the crust or surface layer *(see at right).* The distance from the Earth's surface to its center or core is approximately 4,000 miles. The core may once have been entirely molten, but, as the planet cooled, the inner core (about 1,500 miles thick) solidified. The outer core (about 1,400 miles thick) remains molten and is surrounded by a 1,800 mile thick mantle of dense, mostly solid rock. Above this layer is the relatively thin crust, three to forty-eight miles thick, on which the continents and ocean floors are found.



The Earth's lithosphere (crust and upper mantle) is divided into many plates, all of which are in constant motion. Where plate edges meet, one plate may slide past another, one plate may be driven beneath another (subduction), or upwelling volcanic material pushes the plates apart at mid-ocean ridges. Continental plates are made of less dense rocks (granites) than oceanic plates (basalts) and thus, "ride" higher than oceanic plates. Many theories have been proposed to explain crustal plate movement. Currently, most evidence supports the theory that convection currents in the partially molten asthenosphere (the zone of mantle beneath the lithosphere) move the rigid crustal plates above. The volcanism that has so greatly shaped today's Yellowstone is a product of plate movement combined with upwellings of molten rock, as described on the next pages.

3

Ancient Yellowstone

Illustrations on pages 36, 37, 38, and 44 adapted with permission from Windows Into the Earth, *Dr. Robert Smith and Lee J. Siegel, 2000.*

50–40 million years ago
—Absaroka Volcanics—

This chapter focuses on events and processes of the last 20 million years that have created the park we see today— a tiny fraction of the 4.6 billion years of the planet's existence.

Most of Earth's history (from the beginning to approximately 570 million years ago) is known as the Precambrian era. Rocks of this age are found in northern Yellowstone and in the hearts of the Teton, Beartooth, Wind River, and Gros Ventre ranges. Throughout much of this era, the West was repeatedly flooded by ancient seas. During the Paleozoic and Mesozoic eras (570 to 66 million years ago), this area was covered at times by ocean. At other times it was a land of sand dunes, tidal flats, and vast plains. Near the end of this era, mountain building processes created the Rocky Mountains.

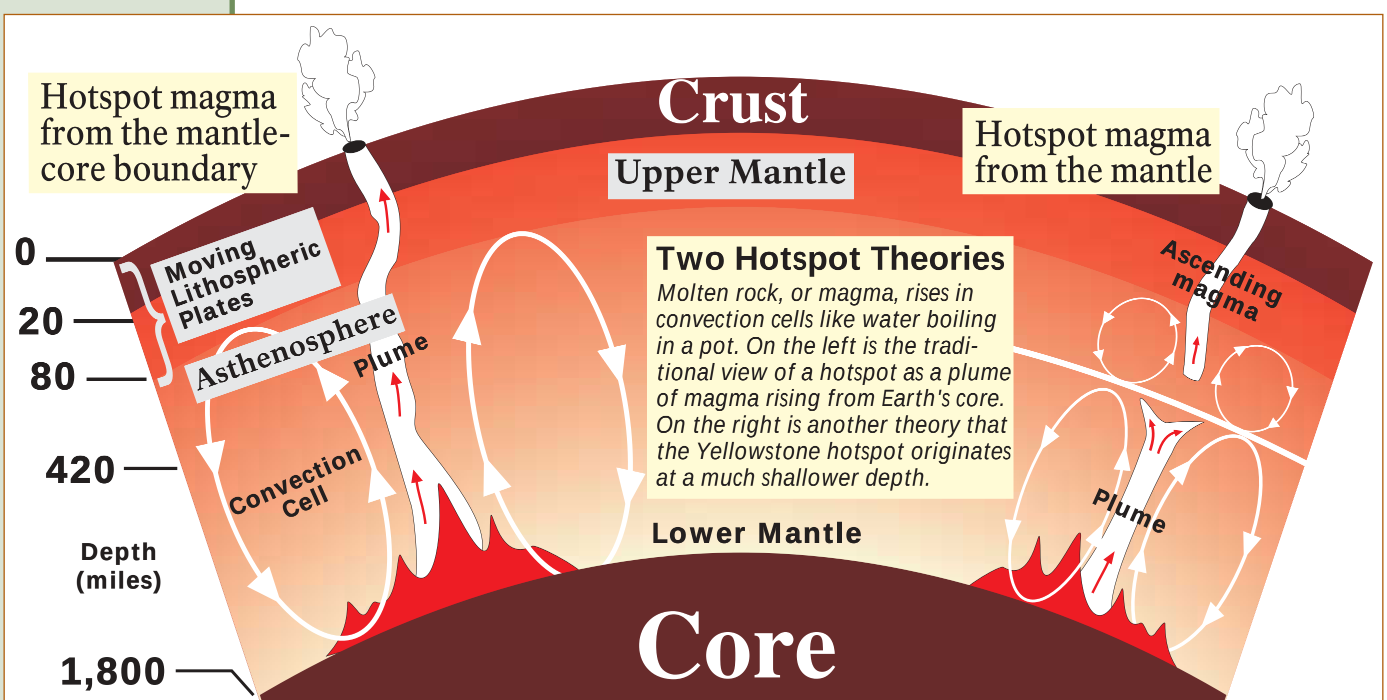
During the Cenozoic era (approximately the last 66 million years of Earth's history), widespread mountain-building, volcanism, faulting, and glaciation sculpted the Yellowstone area. The Absaroka Range along the park's north and east sides was formed by numerous volcanic eruptions about 50 million years ago. Volcanic debris buried trees that are seen today as fossilized remnants along Specimen Ridge in northern Yellowstone. This period of volcanism is not related to the present Yellowstone volcano.

Approximately 30 million years ago, vast expanses of the West began stretching apart along an east-west axis. This stretching process increased about 17 million years ago and continues today, creating the modern basin and range topography (north-south mountain ranges interspersed with long north-south valleys) characterizing much of the Western landscape.

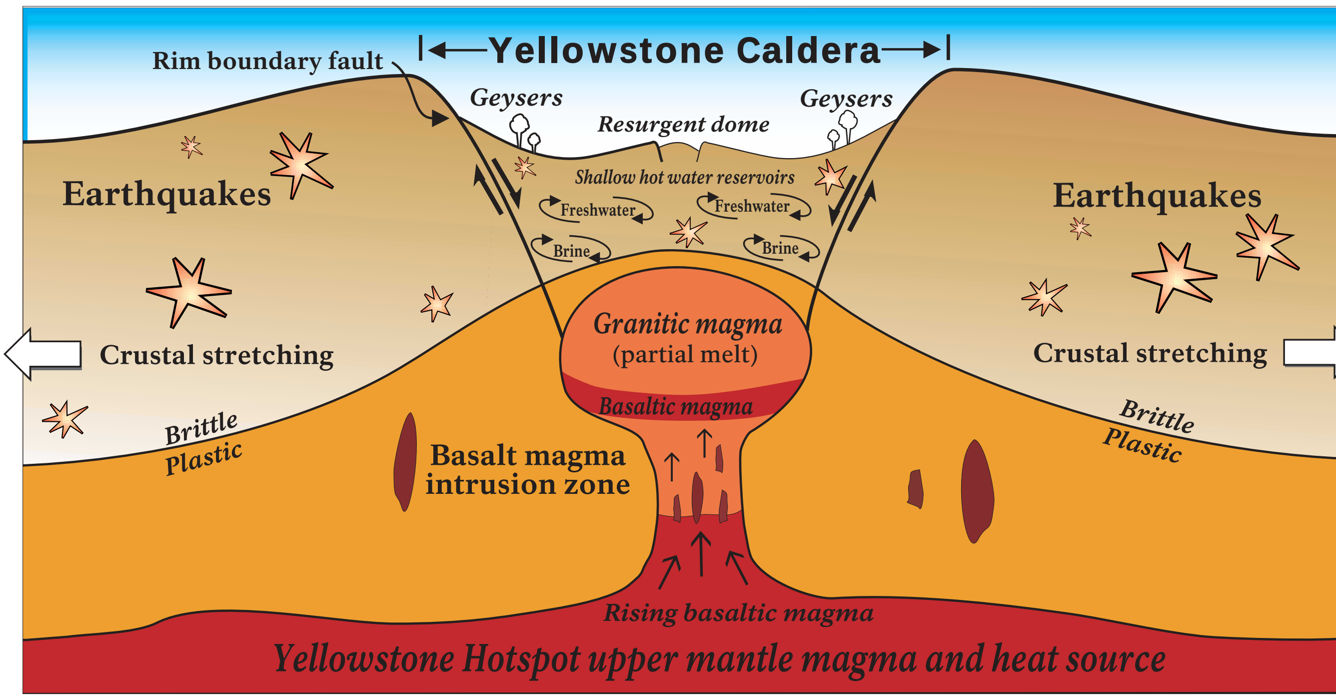
About 16.5 million years ago, a great period of volcanism appeared near the area now marked by the convergence of the Nevada, Oregon, and Idaho state lines. A geologic phenomenon known as a hotspot triggered this period of repeated volcanic eruptions that can be traced across southern Idaho into Yellowstone National Park. This volcanism with its underlying hotspot remains a driving force in Yellowstone today.

The Hotspot Rules

Hotspots are among the primal forces arising from within the Earth to affect its surface. They are always associated with some form of extensive volcanic activity. The Yellowstone volcano is fueled by a rare continental hotspot (most known hotspots are located beneath oceanic crust). How hotspots arise and their ultimate demise is the subject of much scientific research and discussion.



Hotspots form where hotter or molten rock rises due to variations in rock temperatures or densities. Traditional hotspot theory holds that a plume of molten rock rises all the way from Earth's core-mantle boundary to trigger volcanic eruptions at the surface *(see illustration on previous page).* Newer theories relate the rise of molten rock to areas in Earth's

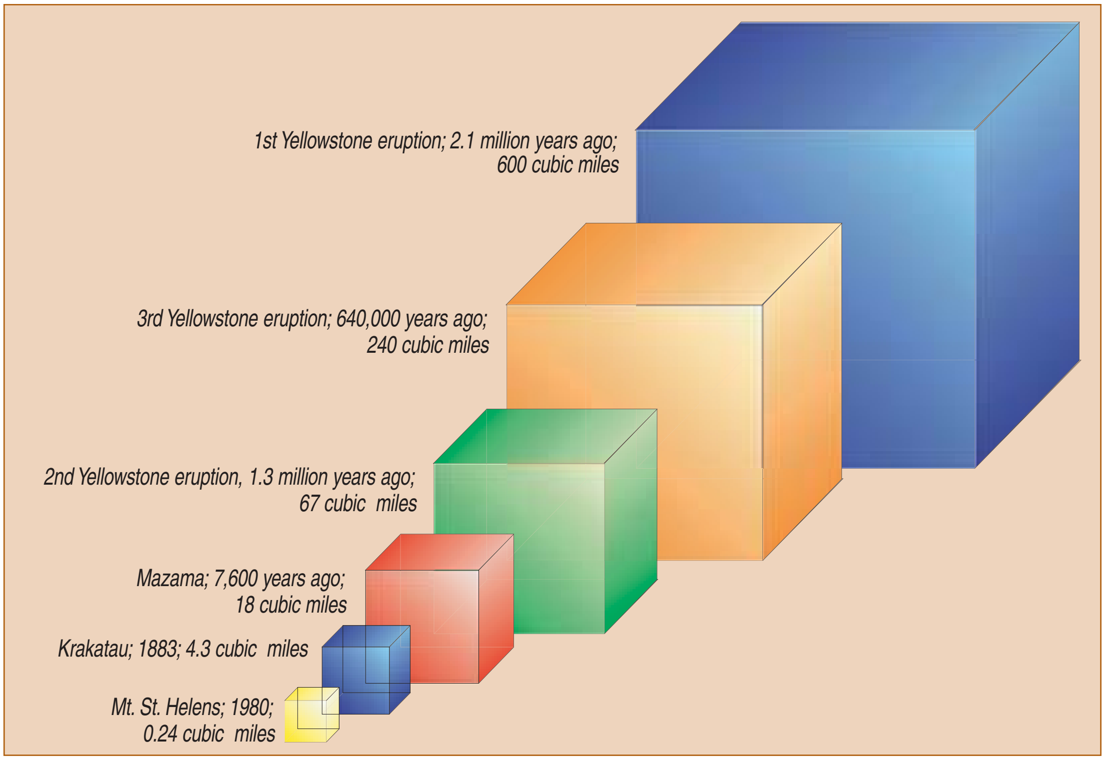


crust weakened by stretching and thinning such as that which is ongoing throughout the interior West. Some of these theories also propose a shallower mantle origin for hotspots.

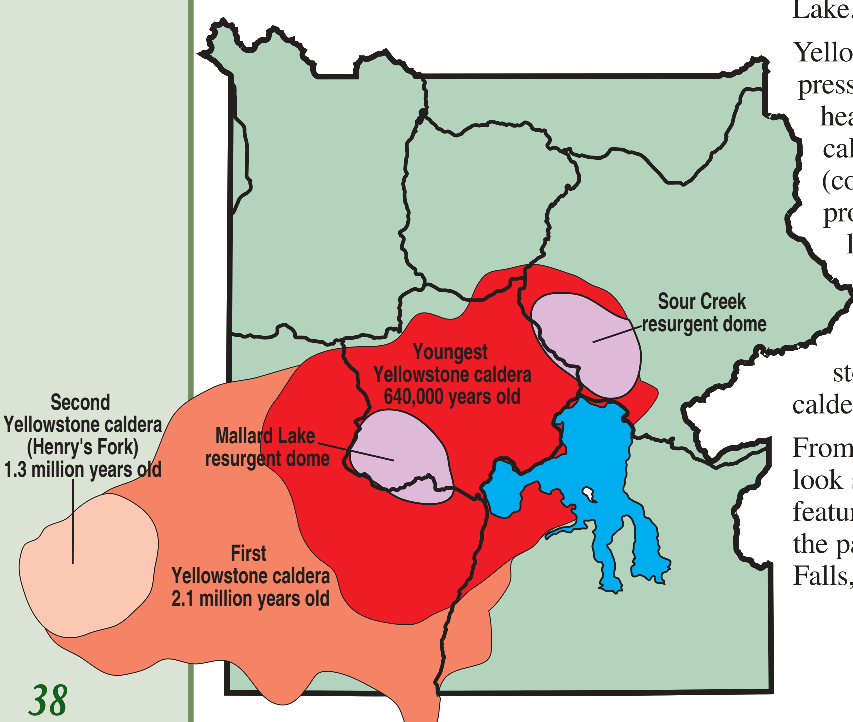
Regardless of its origins and subsurface behavior, the hotspot that feeds Yellowstone's volcano has been active for some 16.5 million years, repeatedly erupting and leaving a track of 100 gigantic calderas (craters) across 500 miles from the Nevada-Oregon border northeast up Idaho's Snake River Plain and into central Yellowstone. This trail of evidence was created as the North American plate moved in a southwestern direction over the hotspot. The hotspot also causes Earth's surface to bulge above it, notable in the Yellowstone area where the average elevation is 1,700 feet higher than surrounding regions.

About 2.1 million years ago, the movement of the North American plate brought the Yellowstone area into proximity with the hotspot. The heat from the hotspot melted rocks in the crust, creating a magma chamber of partially molten, partially solid rock *(see below).* Upward pressure from the magma chamber caused bulging above it. This pressure caused the overlying rocks to break, forming faults and causing earthquakes. Eventually, these faults reached the deep magma chamber. Magma oozed through these cracks, releasing pressure within the chamber and allowing trapped gases to rapidly expand. A massive eruption then occurred, spewing volcanic ash and gas high into the atmosphere and causing fast-moving superhot pyroclastic flows on the ground. As the underground magma chamber emptied, the ground above it sunk, creating a huge crater known as the Huckleberry Ridge Caldera. Smaller lava flows eventually filled in the caldera over tens to hundreds of thousands of years.

At Yellowstone and some other volcanoes, some scientists theorize that Earth's crust fractures and cracks in a concentric or ring-fracture pattern. At some point these cracks reach the magma "reservoir," release the pressure, and the volcano explodes. The huge amount of material released causes the volcano to collapse into a huge steaming crater—a caldera.



The volume of material ejected during this eruption is estimated to have been 2,400 times that size of the 1980 eruption of Mt. St. Helens in Washington *(see illustration above),* and ash has been found as far away as Missouri. Approximately 800,000 years later, a second, smaller volcanic eruption occurred on the western edge of the Huckleberry Ridge Caldera and created the Henry's Fork Caldera. Then 640,000 years ago, the third massive volcanic eruption in central Yellow stone created the Yellowstone Caldera, 30 by 45 miles in size. Approximately 30 smaller eruptions and lava flows have occurred since this last major eruption, the last dating about 70,000 years ago. About 162,000 years ago, a volcanic eruption created a smaller caldera now filled by the West Thumb of Yellowstone Lake.



Yellowstone remains atop the hotspot. The pressure and movement of the underlying heat, magma, and fluids cause the entire caldera floor to inflate and deflate rapidly (compared to more typical geologic processes). This movement has created two large bulges in the earth called resurgent domes (Sour Creek and Mallard Lake), which we see as large hills. Ongoing studies indicate that Yellow-stone is a dynamic system in which the caldera floor is in almost constant motion.

From the summit of Mt. Washburn, one can look south into much of this vast volcanic feature. The caldera rim is also visible along the park road system at Gibbon Falls, Lewis Falls, and Lake Butte.

Geyser Basin Systems

Yellowstone's hydrothermal features would not exist without the underlying magma body that releases tremendous heat. They also depend on sources of water, such as in the mountains surrounding the Yellowstone Plateau. There, snow and rain slowly percolate through layers of porous rock riddled with cracks and fissures. Some of this cold water meets hot saline brine that is directly heated by the shallow magma body. The water's temperature rises well above the boiling point but the water remains in a liquid state due to the great pressure and weight of the overlying rock and water. The result is superheated water with temperatures exceeding 400°F.

The superheated water is less dense than the colder, heavier water sinking around it. This creates convection currents that allow the lighter, more buoyant, superheated water to begin its slow journey back to the surface following the cracks, fissures, and weak areas through rhyolitic lava flows. As hot water travels through this rock, high temperatures dissolve some of silica in the rhyolite.

While in solution underground, some silica coats the walls of the cracks and fissures to form a nearly pressure-tight seal. This locks in the hot water and creates a "plumbing system" that can withstand the great pressure needed to produce a geyser. At the surface, silica precipitates to form either geyserite or sinter, creating the massive geyser cones, the scalloped edges of hot springs, and the seemingly barren landscape of geyser basins.

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__Geysers__ are hot springs with constrictions in their plumbing, usually near the surface, that prevent water from circulating freely to the surface where heat would escape. The deepest circulating water can exceed the surface boiling point (199°F/93°C). Surrounding pressure also increases with depth, much as it does with depth in the ocean. Increased pressure exerted by the enormous weight of the overlying rock and water prevents the water from boiling. As the water rises, steam forms. Bubbling upward, steam expands as it nears the top of the water column until the bubbles are too large and numerous to pass freely through the tight spots. At a critical point, the confined bubbles actually lift the water above, causing the geyser to splash or overflow. This decreases pressure on the system, and violent boiling results. Tremendous amounts of steam force water out of the vent, and an eruption begins. Water is expelled faster than it can enter the geyser's plumbing system, and the heat and pressure gradually decrease. The eruption stops when the water reservoir is depleted or when the system cools.

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__Geyser basin landscapes,__ as at Norris (above right), owe their light, barren appearance to a rock called sinter. __Cone geysers,__ such as Riverside in Upper Geyser Basin (above) erupt in a narrow jet of water, usually from a cone. __Fountain geysers,__ such as Echinus in Norris Geyser Basin (right) shoot water in various directions, typically from a pool.

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Hydrothermal Features

Fumaroles *or steam vents, are the hottest hydrothermal features in the park. They have so little water that it all flashes into steam before reaching the surface. At places like Roaring Mountain (right), the result is a loud hissing of steam and gases.*

Travertine terraces, *found at Mammoth Hot Springs (right), are formed from limestone (calcium carbonate). Thermal waters rise through the limestone, carrying high amounts of dissolved carbonate. At the surface, carbon dioxide is released and calcium carbonate is deposited as travertine, the chalky white rock of the terraces. Due to the rapid rate of deposition, these features constantly and quickly change.*

Mudpots *such as Fountain Paint Pot (center, right) are acidic hot springs with a limited water supply. Some micro-organisms use hydrogen sulfide, which rises from deep within the earth, as an energy source. They help convert the gas to sulfuric acid, which breaks down rock into clay. Various gases escape through the wet clay mud, causing it to bubble. Mudpot consistency and activity vary with the seasons and precipitation.*

Hot Springs *such as this one at West Thumb (right) are the most common hydrothermal features in the park. Their plumbing has no constrictions. Superheated water cools as it reaches the surface, sinks, and is replaced by hotter water from below. This circulation, called convection, prevents water from reaching the temperature needed to set off an eruption.*

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Beneath Yellowstone Lake

In 1997, researchers saw anomalies on the floor of Bridge Bay using an echo sounder. They deployed a submersible remotely operated vehicle (ROV), equipped with photographic equipment and sector-scan sonar. Large targets immediately appeared on the sonar image then suddenly very large, looming, spire-like structures appeared in the photographic field of view *(photo at right)*. The researchers recognized these structures were similar to structures seen in deep ocean areas, such as the Mid-Atlantic Ridge and the Juan de Fuca Ridge.

Since this discovery, scientists from the U.S. Geological Survey and a private company, Eastern Oceanics, have been surveying the bottom of Yellowstone Lake and discovering many underwater hydrothermal features and obtaining geologic data. Using high-resolution, multi-beam sonar imaging and seismic reflection, they completed a four-year mapping of Yellowstone Lake in 2002.

Most of the lake is inside the 640,000-year-old Yellowstone caldera. Features mapped include large craters; spires composed primarily of bacteria, diatoms, and silica; domal features containing gas pockets, deformed sediments, and hundreds of hydrothermal vents; and recent, previously unmapped faults, landslide deposits, and submerged older lake shorelines. These features are draped above an undulating surface of rhyolitic lava flows and active fissures. South of the caldera in the southern reaches of the

Divers on this boat (above) descended the lake's cold waters to photograph and collect specimens from spires (below) that no one knew existed a decade ago. Scientists think these

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lake, the floor is dominated by glacial deposits similar to glacial terrains seen in Jackson Hole, south of the park.

Formation of hydro-thermal spires and craters is related to deep-seated hydro-thermal processes. Craters result from hydrothermal explosions caused by water flashing to steam often accompanied by failure and fragmentation of overlying caprock. Spires, composed of sinter, may be formed in a way similar to black smoker chimneys—hydrothermal features associated with oceanic plate boundaries.

Studies show the Yellowstone caldera has cycles of inflation and deflation. The underwater geologic history integrated with the exposed shoreline history will help define the chronology and duration of these cycles. Further analysis of the data and direct investigations using an ROV may identify the relationship of fish and other fauna to these important hydrothermal influences on the ecosystem, including locations of lake trout spawning sites.

The research goal to obtain a high-resolution bathymetric map of Yellowstone Lake has been achieved. Most of the lake bottom features have been located and described. These new surveys give an accurate picture of the geologic forces shaping Yellowstone Lake, identify potential geologic hazards located in the lake, and determine geologic influences affecting the present-day aquatic biosphere.

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Illustrations on this page are courtesy of Dr. Lisa A. Morgan, U.S.G.S. Research Geologist

Earthquakes

Earthquakes occur along fault zones in the crust where forces from crustal plate movement build to a significant level. The rock along these faults becomes so stressed that eventually it slips or breaks. Energy is then released as shock waves (seismic waves) that reverberate throughout the surrounding rock.

Different kinds of seismic waves are released inside the earth during an earthquake. Primary waves ("P-waves") move quickly in the direction of travel, compressing and stretching the rock. Secondary waves ("S-waves") move up, down, and sideways through rock in a rolling motion. Once a seismic wave reaches the surface of the earth, it may be felt. Surface waves affect the ground, which can roll, crack open, or be vertically and/or laterally displaced. Structures are susceptible to earthquake damage because the ground motion is usually horizontal.

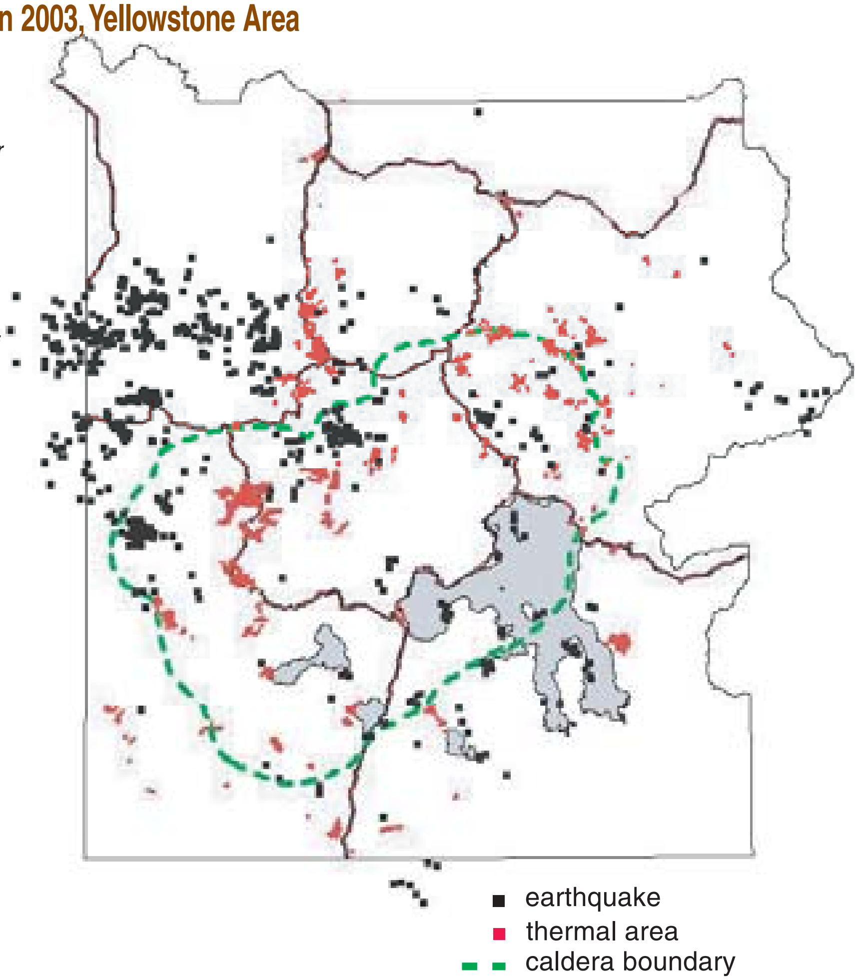
Earthquakes in Yellowstone help to maintain hydrothermal activity by keeping the "plumbing" system open. Without the periodic disturbance of relatively small earthquakes, the small fractures and conduits that supply hot water to geysers and hot springs might be sealed by mineral deposition. Some earthquakes generate changes in Yellowstone's hydrothermal systems. For example, the 1959 Hebgen Lake and 1983 Borah Peak earthquakes caused measurable changes in Old Faithful Geyser and other hydrothermal features.

Earthquakes help us understand the subsurface geology around and beneath Yellowstone. The energy from earthquakes travels through hard and molten rock at different rates. We can "see" the subsurface and make images of the magma chamber and the caldera by "reading" the energy emitted during earthquakes. An extensive geological monitoring system is in place to aid in that interpretation.

1,124 Earthquakes in 2003, Yellowstone Area

Yellowstone is the most seismically active area in the Intermountain West. An average of 2000 earthquakes occur each year in the Yellowstone area—most are not felt.

Real-time data about earthquakes in Yellowstone is at www.seis.utah.edu, a website maintained by the University of Utah Seismograph Stations.



Scales of Magnitude

The size of an earthquake is given by its magnitude, which is often referred to as Richter Magnitude. On this scale, the amplitude of shaking goes up by a factor of 10 for each unit on the scale. Thus, at the same distance from the earthquake, the shaking will be 10 times as large during a magnitude 5 earthquake as during a magnitude 4 earthquake. The total amount of energy released by the earthquake, however, goes up by a factor of 32. There are many different ways that magnitude is measured from seismograms, partially because each method only works over a limited range of magnitudes and with different types of seismometers. But, all of the methods are designed to agree well over the range where they overlap.

The methods used in University of Utah earthquake listings include:

ML—local magnitude, the original scale defined by Richter and Gutenberg based on the maximum amplitude of the waves. This is the preferred magnitude, when available.

MC—coda magnitude, based on measurements of the duration of the seismic waves for earthquakes up to about magnitude 5.

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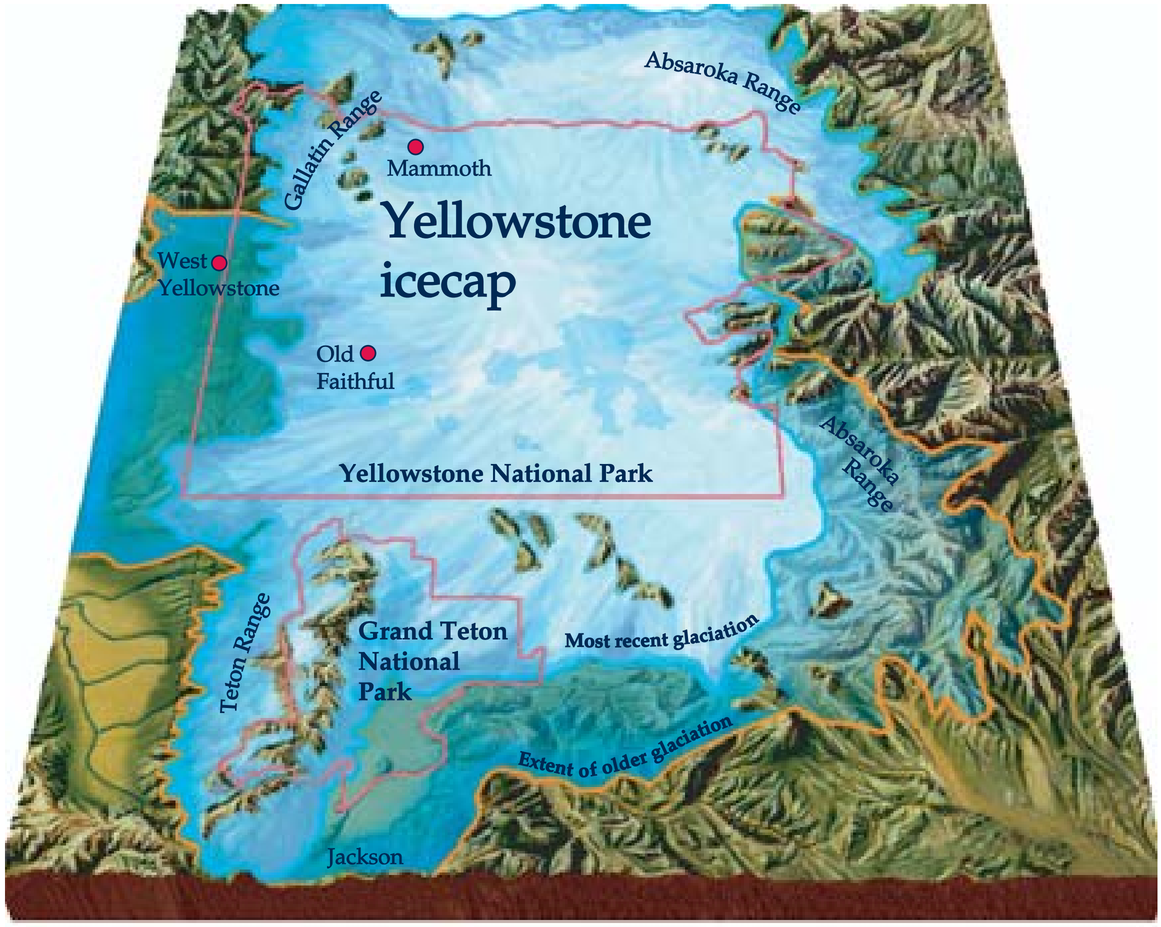
Glaciers



The extent of two major glaciations are shown on this map:
Bull Lake—orange outline
Pinedale—blue outline

Scientific understanding of glacier dates, sequence, and extent continues to evolve, and varying information appears in different references (including previous editions of this book). The information here is considered current by Yellowstone's geologist as of March 2004.

Glaciers

Glaciers result when, for a period of years, more snow falls in an area than melts. Once the snow reaches a certain depth, it turns into ice and begins to move under the the force of gravity or the pressure of its own weight. During this movement, rocks are picked up and carried in the ice, and these rocks grind Earth's surface, eroding and carrying material away. Glaciers also deposit materials. Large U-shaped valleys, ridges of debris (moraines), and out-of-place boulders (erratics) are evidence of a glacier's passing.

Yellowstone and much of North America have experienced numerous periods of glaciation during the last two million years. Succeeding periods of glaciation have destroyed most surface evidence of previous glacial periods, but scientists have found evidence of them in sediment cores taken on land and in the ocean.

The Bull Lake Period glaciers covered the region about 140,000 years ago. Evidence exists that this glacial episode extended farther south and west of Yellowstone than the subsequent Pinedale Glaciation *(described in the next paragraph),* but no evidence of it is found to the north and east. This indicates that the Pinedale Glaciation destroyed surface evidence of Bull Lake Glaciation in these areas.

In the Yellowstone region, the last (and most studied) major glaciation, the Pinedale, may have begun as early as 70,000 years ago. It ended more than 14,000 years ago. At the peak of the Pinedale Glaciation—25,000 years ago—nearly all of today's Yellowstone National Park was covered by a huge ice cap 4,000 feet thick (at a point above present-day Yellowstone Lake, *see above).* Mount Washburn and Mount Sheridan were both completely covered by ice. This ice field was not part of the continental ice sheet extending south from Canada. The ice field occurred here, in part, because the hotspot beneath Yellowstone had pushed up the area to a higher elevation with colder temperatures and more precipitation than the surrounding land.

Sedimentation & Erosion

Not all the rocks in Yellowstone are of "recent" volcanic origin. Precambrian igneous and metamorphic rock in the northeastern portion of the park and Beartooth Mountains are at least 2.7 billion years old. These rocks are very hard and erode slowly.

Sedimentary sandstones and shales, deposited by seas during the Paleozoic and Mesozoic eras (570 million to 66 million years ago) can be seen in the Gallatin Range and Mount Everts. Sedimentary rocks in Yellowstone tend to erode more easily than the Precambrian rocks.

Weathering breaks down earth materials from large sizes to small particles, and happens in place. The freeze/thaw action of ice is one type of weathering common in Yellowstone. Agents of erosion—wind, water, ice, and waves—move weathered materials from one place to another.

When erosion takes place, sedimentation—the deposition of material—also eventually occurs. Through time, sediments are buried by more sediments and the material hardens into rock. This rock is eventually exposed (through erosion, uplift, and/or faulting), and the cycle repeats itself. Sedimentation and erosion are "reshapers" and "refiners" of the landscape—and they also expose Yellowstone's past life as seen in fossils like the petrified trees.

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The Beartooth Mountains northeast of Yellowstone (left) are actually an uplifted block of Precambrian rock.

Mt. Everts, near Mammoth, (below) exposes sedimentary rock, which erodes easily and often tumbles into Gardner Canyon.

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Fossils

Paleobotany

Nearly 150 species of fossil plants (exclusive of fossil pollen specimens) from Yellowstone have been described, including ferns, horsetail rushes, conifers and deciduous plants such as sycamores, walnuts, oaks, chestnuts, maples, and hickories. Sequoia is abundant, and other species such as spruce and fir are also present.

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In Yellowstone, many petrified trees can be seen. Resulting from volcanic eruptions about 50 million years ago, they present questions that scientists continue to ponder: Were the trees petrified in place and thus represent layers of forest? Or were they scattered before and after petrification, which means the number of forests cannot be determined?

Most petrified wood and other plant fossils come from Eocene deposits about 50 million years old, which occur in many northern parts of the park, including the Gallatin Range, Specimen Creek, Tower, Crescent Hill, Elk Creek, Specimen Ridge, Bison Peak, Barronette Peak, Abiathar Peak, Mount Norris, Cache Creek, and Miller Creek. Petrified wood is also found along streams in areas east of Yellowstone Lake. The most accessible petrified tree site is on Specimen Ridge.

The first fossil plants from Yellowstone were collected by the early Hayden Survey parties. In his 1878 report, Holmes made the first reference to Yellowstone's fossil "forests." The report identified the petrified trees on the north slope of Amethyst Mountain opposite the mouth of Soda Butte Creek, about eight miles southeast of Junction Butte.

Around 1900, F.H. Knowlton identified 147 species of fossil plants from Yellowstone, 81 of them new to science. He also proposed the theory that the petrified trees on the northwest end of Specimen Ridge were forests petrified in place.

Another theory proposes that the trees were uprooted by volcanic debris flows and transported to lower elevations. The 1980 eruption of Mount St. Helens supported this idea. Mud flows not only transported trees to lower elevations, they also deposited the trees upright.

Cretaceous marine and nonmarine sediments are exposed on Mount Everts. The area is under study; fossil leaves, ferns, clam-like fossils, shark teeth, and several species of vertebrates have been found. In 1994 fossil plants were discovered in Yellowstone during the East Entrance road construction project, which uncovered areas containing fossil sycamore leaves and petrified wood.

Fossil Invertebrates

Fossil invertebrates are abundant in Paleozoic rocks, especially the limestones associated with the Madison Group in the northern and south-central parts of the park. They include corals, bryozoans, brachiopods, trilobites, gastropods, and crinoids. Trace fossils, such as channeling and burrowing of worms, are found in some petrified tree bark.

Fossil Vertebrates

Fossil remains of vertebrates are rare, but perhaps only because of insufficient field research. A one-day survey led by paleontologist Jack Horner, of the Museum of the Rockies, Bozeman, Montana, resulted in the discovery of the skeleton of a Cretaceous vertebrate. Other vertebrate fossils found in Yellowstone include:

- Fish: crushing tooth plate; phosphatized fish bones; fish scales; fish teeth.
- Horse: possible Pleistocene horse, *Equus nebraskensis,* reported in 1939.
- Other mammals: Holocene mammals recovered from Lamar Cave; Titanothere (type of rhinocerus) tooth and mandible found on Mt. Hornaday in 1999.

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Dr. Robert Smith and assistant set up a temporary seismographic station. It is one of dozens throughout the Greater Yellowstone Ecosystem sending seismic data to researchers at the University of Utah.

Yellowstone As a Geologic Laboratory

Yellowstone is a unique outdoor laboratory for research scientists. Many of these scientific studies have ramifications far beyond Yellowstone National Park. Current research examples:

- Earthquake monitoring stations detect the numerous daily tremors occurring in the Yellowstone region, and the patterns are studied to develop an understanding of the geodynamics of Yellowstone's hotspot.
- Studies on the location of previously unmapped geologic structures should help us understand what controls subsurface fluid flow and recharge in geothermal systems.
- Baseline geochemical studies help distinguish between human and natural influences on the underground water network in the region.
- Underwater studies in Yellowstone Lake have identified hydrothermal vents where organisms have been found that survive on sulphur emissions and that resemble life found under the ocean near similar hydrothermal vents; comparison studies continue.
- The deposition of sinter around hydrothermal springs is being studied to understand how early life developed on Earth and to look for similarities on other planets, particularly Mars.
- Thermophiles, microorganisms that can live in extreme environments, are being collected from the park's hydrothermal features, identified, and their heat-resistant enzymes are being studied. Some already are being used in a variety of medical and forensic processes. *(See Chapter 8.)*

All scientists in Yellowstone work under special permits and are closely supervised by National Park Service staff.

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For More Information

Additional Information from Yellowstone National Park

Yellowstone National Park website, www.nps.gov/yell, includes an array of park information about resources, science, recreation, and issues.

Yellowstone Science, published quarterly, reports on research and includes articles on natural and cultural resources. Free from the Yellowstone Center for Resources, in the Yellowstone Research Library, or online at www.nps.gov/yell.

Yellowstone Today, published seasonally and distributed at entrance gates and visitor centers, includes features on park resources such as hydrothermal features.

Area trail guides detail geology of major areas of the park. Available for a modest donation at Canyon, Fountain Paint Pot, Mammoth, Norris, Old Faithful, and West Thumb areas.

Site Bulletins, published as needed, provide more detailed information on park topics such as bison management, lake trout, grizzly bears, and wolves. Free; available upon request from visitor centers.

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Additional information available on numerous other websites.

Videos

The Complete Yellowstone

Yellowstone: Imprints of Time

Yellowstone Revealed

Yellowstone: A Symphony of Fire and Ice